Fluid-Attenuated Inversion Recovery Vascular Hyperintensity Topography, Novel Imaging Marker for Revascularization in Middle Cerebral Artery Occlusion

Dezhi Liu, MD*; Fabien Scalzo, PhD*; Neal M. Rao, MD; Jason D. Hinman, MD; Doojin Kim, MD; Latiska K. Ali, MD; Jeffrey L. Saver, MD; Wen Sun, MD, PhD; Qiliang Dai, MD, PhD; Xinfeng Liu, MD, PhD; David S. Liebeskind, MD

Background and Purpose—In acute arterial occlusion, fluid-attenuated inversion recovery vascular hyperintensity (FVH) has been linked to slow flow in leptomeningeal collaterals and cerebral hypoperfusion, but the impact on clinical outcome is still controversial. In this study, we aimed to investigate the association between FVH topography or FVH-Alberta Stroke Program Early CT Score (ASPECTS) pattern and outcome in acute M1-middle cerebral artery occlusion patients with endovascular treatment.

Methods—We included acute M1-middle cerebral artery occlusion patients treated with endovascular therapy (ET). All patients had diffusion-weighted imaging (DWI) and fluid-attenuated inversion recovery before ET. Distal FVH-ASPECTS was evaluated according to distal middle cerebral artery-ASPECT area (M1–M6) and acute DWI lesion was also reviewed. The presence of FVH inside and outside DWI-positive lesions was separately analyzed. Clinical outcome after ET was analyzed with respect to different distal FVH-ASPECTS topography.

Results—Among 101 patients who met inclusion criteria for the study, mean age was 66.2±17.8 years and median National Institutes of Health Stroke Scale was 17.0 (interquartile range, 12.0–21.0). FVH-ASPECTS measured outside of the DWI lesion was significantly higher in patients with good outcome (modified Rankin Scale [mRS] score of 0–2; 8.0 versus 4.0, P<0.001). Logistic regression demonstrated that FVH-ASPECTS outside of the DWI lesion was independently associated with clinical outcome of these patients (odds ratio, 1.3; 95% confidence interval, 1.06–1.68; P=0.013). FVH-ASPECTS inside the DWI lesion was associated with hemorrhagic transformation (odds ratio, 1.3; 95% confidence interval, 1.04–1.51; P=0.019).

Conclusions—Higher FVH-ASPECTS measured outside the DWI lesion is associated with good clinical outcomes in patients undergoing ET. FVH-ASPECTS measured inside the DWI lesion was predictive of hemorrhagic transformation. The FVH pattern, not number, can serve as an imaging selection marker for ET in acute middle cerebral artery occlusion.

Key Words: hypertension ■ magnetic resonance imaging ■ middle cerebral artery occlusion ■ stroke ■ thrombectomy

Received May 4, 2016; final revision received July 28, 2016; accepted August 12, 2016.

From the Department of Neurology, Jinling Hospital, Nanjing University School of Medicine, Nanjing, China (D.L., W.S., Q.D., X.L.); and Department of Neurology, Neurovascular Imaging Research Core (D.L., F.S., D.S.L.) and Department of Neurology, UCLA Stroke Center (D.L., F.S., N.M.R., J.D.H., D.K., L.K.A., J.L.S., D.S.L.), University of California Los Angeles.

Guest Editor for this article was Georgios Tsivgoulis, MD.

*Drs Liu and Scalzo contributed equally.


Reprint requests to David S. Liebeskind, MD, Department of Neurology, Neurovascular Imaging Research Core, University of California Los Angeles, Los Angeles, CA, E-mail davidliebeskind@yahoo.com or Xinfeng Liu, MD, PhD, Department of Neurology, Jinling Hospital, Nanjing University School of Medicine, 305 East Zhongshan Rd, Nanjing 210002, Jiangsu Province, PR China, E-mail xlliu2@vip.163.com

© 2016 American Heart Association, Inc.

Stroke is available at http://stroke.ahajournals.org

DOI: 10.1161/STROKEAHA.116.013953
populations, end points, and FVH classifications. However, we found that all these studies focused solely on the presence or number of FVHs, rather than the topography or pattern of FVHs. Furthermore, the juxtaposition of FVH relative to established diffusion-weighted imaging (DWI) lesions indicative of core infarction may be linked with subsequent imaging and clinical outcomes.

The purpose of this study was to prospectively assess the association between FVH-ASPECTS pattern or topography and the outcome of patients with acute middle cerebral artery (MCA) occlusion.

**Patients and Methods**

**Patients and Clinical Assessment**

We prospectively evaluated consecutive patients who received ET (intra-arterial thrombolytic therapy, or mechanical thrombectomy) for acute cerebral ischemia between September 2004 and December 2014. Patients were included in our study if they had initial imaging demonstrating occlusion of proximal M1 segment of the MCA, and underwent conventional angiography for consideration of ET. The patients were excluded if they did not undergo MRI scan or the imaging could not be analyzed. Patients were also excluded if tandem vessel occlusions (ie, internal carotid artery+MCA) were identified. Finally, 101 patients were included in the analysis. Demographic, clinical, and laboratory data were retrieved from a prospectively maintained, single-center data set of consecutive cases. The following stroke risks factors were identified: age, sex, hypertension, diabetes mellitus, hyperlipidemia, previous stroke/transient ischemic attack, coronary artery disease, chronic heart failure, and arterial fibrillation. Baseline characteristics, including National Institutes of Health Stroke Scale (NIHSS), systolic blood pressure, diastolic blood pressure, blood glucose, and cholesterol, and previous medications were also collected from these patients.

**Imaging Analysis**

All patients’ imaging data were reviewed at UCLA Neurovascular Imaging Research Core by 2 authors (D.L. and W.S). All MRI studies included DWI and fluid-attenuated inversion recovery. DWI lesion volume measurement was performed by one of the authors (F.S.) blinded to the clinical information using a computer-assisted volumetric analysis program (Olea Medical, La Ciotat, France). Diffusion was measured at 3 values of b (b=0, 500, 1000 s/mm2), and average apparent diffusion coefficient maps were generated. DWI volumes were quantified from analysis of isotropic b1000 images and apparent diffusion coefficient maps with threshold of apparent diffusion coefficient <600. Determination of M1 occlusion was made by review of angiographic images. Hemorrhagic transformation (HT) was defined as a new hyperattenuated region identified on any follow-up CT scan before patient discharge, as previously described. In all cases, angiography was performed subsequent to the initial MRI study.

FVH were defined as focal, tubular, or serpentine hyperintensities in the subarachnoid space relative to CSF and corresponding to the typical arterial course. As shown in Figure 1, Total FVH-Alberta Stroke Program Early CT Score (FVH-T-ASPECTS) was assessed according to distal MCA-ASPECTS area (M1–M6). FVH in every distal MCA-ASPECTS area was separately evaluated. For example, no FVH in M1 area was recorded as 0, less than M1 half area was recorded as 1, and more than M1 half area was recorded as 2. Those distal MCA-ASPECTS areas were defined as DWI-positive area if there was acute infarction lesion in the areas. FVH-ASPECTS outside DWI-positive area (FVH-O-ASPECTS) and FVH-ASPECTS inside DWI-positive area (FVH-I-ASPECTS) were separately analyzed. Then, FVH-I-ASPECTS was graded as subtle FVH-I-ASPECTS (0–2 points) and prominent FVH-I-ASPECTS (>2 points). Similar to that, FVH-O-ASPECTS was graded as subtle FVH-O-ASPECTS (0–4 points) and prominent FVH-O-ASPECTS (>4 points).

Angiographic collateral grade was evaluated with the American Society of Interventional and therapeutic neuroradiology/society of Interventional Radiology (ASITN/SIR) Collateral Flow Grading System on baseline angiography. Collateral rating was performed by one author (D.S.L.) with extensive experience in angiographic interpretation in acute stroke, blinded to the clinical presentation and outcomes. Dichotomization was then performed by dividing into groups of 0 to 2 versus 3 to 4. Assessment of vascular recanalization was based on the Thrombolysis in Cerebral Infarction (TICI) scale.

**Figure 1.** A through D. Illustrative case of FVH-Alberta Stroke Program Early CT Score (ASPECTS) evaluation in a patient with a right middle cerebral artery (MCA) occlusion. A. No hyperintense lesions are visible in the right MCA territory. B. Total FVH-ASPECTS (FVH-T-ASPECTS) was 11 (M1=1, M2=2, M3=2, M4=2, M5=2, and M6=2), FVH-ASPECTS outside DWI-positive area (FVH-O-ASPECTS) was 0. C, PWI showed that mismatch on the T_max map was congruent with the fluid-attenuated inversion recovery vascular hyperintensities (FVHs) distribution.
Statistical Analysis
Continuous variables with a normal distribution were described as mean±SD, and non-normally distributed variables were described as median and interquartile range. We compared continuous variables using the Student \( t \) test or Mann–Whitney \( U \) test, as appropriate. Categorical variables were compared using Pearson \( \chi^2 \) or Fisher exact test, as appropriate. Logistic regression analyses were done to determine the independent predictors of favorable clinical outcome and HT. All covariates with a \( P \) value of ≤0.1 in a univariate analysis were entered into this logistic regression model and a value of \( P<0.05 \) was used to indicate statistical significance.

Results
The main baseline characteristics of the patients are summarized in Table 1 and Figure 2. During this period, 101 acute ischemic stroke patients with MCA-M1 occlusion were included in our study. Among these patients, 29 (28.7%) patients were male.

Table 1. Baseline Characteristics in Patients With Different FHV-ASPECTS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Subtle FHV-O-ASPECTS (n=49)</th>
<th>Prominent FHV-O-ASPECTS (n=52)</th>
<th>( P ) Value</th>
<th>Subtle FHV-I-ASPECTS (n=64)</th>
<th>Prominent FHV-I-ASPECTS (n=37)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD</td>
<td>68.2±17.3</td>
<td>64.3±18.2</td>
<td>0.269</td>
<td>66.0±18.6</td>
<td>66.4±16.7</td>
<td>0.925</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>13 (26.5)</td>
<td>16 (30.8)</td>
<td>0.638</td>
<td>17 (26.6)</td>
<td>12 (32.4)</td>
<td>0.530</td>
</tr>
<tr>
<td>Risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>35 (71.4)</td>
<td>35 (67.3)</td>
<td>0.654</td>
<td>44 (68.8)</td>
<td>26 (70.3)</td>
<td>0.873</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>10 (20.4)</td>
<td>10 (19.2)</td>
<td>0.882</td>
<td>12 (18.8)</td>
<td>8 (21.6)</td>
<td>0.727</td>
</tr>
<tr>
<td>Hyperlipidemia, n (%)</td>
<td>16 (32.7)</td>
<td>19 (36.5)</td>
<td>0.682</td>
<td>21 (32.8)</td>
<td>14 (37.8)</td>
<td>0.609</td>
</tr>
<tr>
<td>Stroke/TIA, n (%)</td>
<td>7 (14.3)</td>
<td>2 (3.8)</td>
<td>0.066</td>
<td>7 (10.9)</td>
<td>2 (5.4)</td>
<td>0.347</td>
</tr>
<tr>
<td>CAD, n (%)</td>
<td>8 (16.3)</td>
<td>9 (17.3)</td>
<td>0.895</td>
<td>12 (18.8)</td>
<td>5 (13.5)</td>
<td>0.498</td>
</tr>
<tr>
<td>CHF, n (%)</td>
<td>7 (14.3)</td>
<td>3 (5.8)</td>
<td>0.152</td>
<td>8 (12.5)</td>
<td>2 (5.4)</td>
<td>0.250</td>
</tr>
<tr>
<td>AF, n (%)</td>
<td>23 (46.9)</td>
<td>23 (44.2)</td>
<td>0.785</td>
<td>30 (46.9)</td>
<td>16 (43.2)</td>
<td>0.724</td>
</tr>
<tr>
<td>Initial NIHSS</td>
<td>19.0 (13.0–23.0)</td>
<td>14.5 (11.0–19.8)</td>
<td>0.016*</td>
<td>13.5 (10.0–19.8)</td>
<td>20.0 (15.5–23.0)</td>
<td>0.001*</td>
</tr>
<tr>
<td>SBP, median (IQR), mm Hg</td>
<td>156.4±35.5</td>
<td>151.9±32.2</td>
<td>0.511</td>
<td>154.2±33.5</td>
<td>153.8±34.7</td>
<td>0.960</td>
</tr>
<tr>
<td>DBP, median (IQR), mm Hg</td>
<td>89.0±22.9</td>
<td>84.9±17.4</td>
<td>0.314</td>
<td>87.3±20.2</td>
<td>86.3±20.6</td>
<td>0.815</td>
</tr>
<tr>
<td>Blood glucose, median (IQR), mmol/L</td>
<td>132.5±52.1</td>
<td>132.3±38.9</td>
<td>0.983</td>
<td>127.4±39.9</td>
<td>140.9±53.5</td>
<td>0.154</td>
</tr>
<tr>
<td>Cholesterol, median (IQR), mmol/L</td>
<td>149.1±38.1</td>
<td>167.0±48.9</td>
<td>0.043*</td>
<td>164.7±45.5</td>
<td>147.2±41.6</td>
<td>0.059</td>
</tr>
<tr>
<td>Previous medications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antiplatelet therapy, n (%)</td>
<td>13 (26.5)</td>
<td>10 (19.2)</td>
<td>0.382</td>
<td>14 (21.9)</td>
<td>9 (24.3)</td>
<td>0.777</td>
</tr>
<tr>
<td>Anticoagulation therapy, n (%)</td>
<td>6 (12.2)</td>
<td>7 (13.5)</td>
<td>0.855</td>
<td>11 (17.2)</td>
<td>2 (5.4)</td>
<td>0.088</td>
</tr>
<tr>
<td>Right side</td>
<td>23 (46.9)</td>
<td>28 (53.8)</td>
<td>0.488</td>
<td>34 (53.1)</td>
<td>17 (45.9)</td>
<td>0.487</td>
</tr>
<tr>
<td>Total FHV-ASPECTS</td>
<td>5.0 (3.0–8.0)</td>
<td>10.0 (9.0–11.0)</td>
<td>&lt;0.001*</td>
<td>7.5 (4.0–10.0)</td>
<td>9 (7.0–12.0)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Infarct volume</td>
<td>46.5 (14.6–89.6)</td>
<td>13.7 (6.3–33.7)</td>
<td>0.001*</td>
<td>13.0 (5.9–23.7)</td>
<td>65.0 (30.5–97.5)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>ASITN (0–2)</td>
<td>36 (73.5)</td>
<td>25 (48.1)</td>
<td>0.009*</td>
<td>33 (51.6)</td>
<td>28 (75.7)</td>
<td>0.017</td>
</tr>
<tr>
<td>oTICI (0–2a)</td>
<td>36 (73.5)</td>
<td>26 (50.0)</td>
<td>0.015</td>
<td>39 (60.9)</td>
<td>23 (62.2)</td>
<td>0.903</td>
</tr>
<tr>
<td>IV IPA</td>
<td>23 (46.9)</td>
<td>20 (38.5)</td>
<td>0.389</td>
<td>28 (43.8)</td>
<td>15 (40.5)</td>
<td>0.753</td>
</tr>
<tr>
<td>ET methods</td>
<td>0.789</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.818</td>
</tr>
<tr>
<td>IA IPA</td>
<td>3 (6.1)</td>
<td>3 (5.8)</td>
<td>3 (4.7)</td>
<td>3 (8.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MERCI</td>
<td>26 (53.1)</td>
<td>23 (44.2)</td>
<td>33 (51.6)</td>
<td>16 (43.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solitaire</td>
<td>8 (16.3)</td>
<td>12 (23.1)</td>
<td>12 (18.8)</td>
<td>8 (21.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other methods</td>
<td>12 (24.5)</td>
<td>14 (26.9)</td>
<td>16 (25.0)</td>
<td>10 (27.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT</td>
<td>19 (38.5)</td>
<td>13 (25.0)</td>
<td>0.137</td>
<td>15 (23.4)</td>
<td>17 (45.9)</td>
<td>0.019*</td>
</tr>
<tr>
<td>Discharge mRS ≤2</td>
<td>3 (6.1)</td>
<td>16 (30.8)</td>
<td>0.002*</td>
<td>17 (26.6)</td>
<td>2 (5.4)</td>
<td>0.009*</td>
</tr>
</tbody>
</table>

AF indicates arterial fibrillation; ASITN, American Society of Interventional and Therapeutic Neuroradiology; ASPECTS, Alberta Stroke Program Early CT Score; CAD, coronary artery disease; CHF, chronic heart failure; DBP, diastolic blood pressure; ET, endovascular treatment; FVH, fluid-attenuated inversion recovery vascular hyperintensity; FVH-I-ASPECTS, FVH-ASPECTS inside DWI-positive area; FVH-O-ASPECTS, FVH-ASPECTS outside DWI-positive area; HT, hemorrhagic transformation; IA, intra-arterial; IQR, interquartile range; IV IPA, intravenous tissue-type plasminogen activator; MERCI, Mechanical Embolus Removal in Cerebral Ischemia; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; oTICI, original thrombolysis in cerebral infarction; SBP, systolic blood pressure; and TIA, transient ischemic attack.

* \( P<0.05 \).
and the average age was 66.2±17.8 years. Six patients were treated with intra-arterial tissue-type plasminogen activator, 49 patients were treated with Mechanical Embolus Removal in Cerebral Ischemia (MERCI) device, 20 patients were treated with Solitaire device, 26 patients were treated with other methods (including Penumbra device, mechanical disruption, angioplasty, and all complex methods). Median baseline NIHSS score was 17 (range, 12–21) and median FVH-T-ASPECTS was 9 (range, 5–10). Ninety-eight (98/101, 97.0%) patients have FVH on the fluid-attenuated inversion recovery imaging. FVH were facing the M2, M5, M3, M6, M4, and M1 ASPECTS regions in 97%, 83%, 73%, 56%, 54%, and 46% of patients, respectively (average of 2 readers). The distribution of FVH-T-ASPECTS in different ASPECT areas was also shown in Figure 2.

FVH-O-ASPECTS and FVH-I-ASPECTS
The interobserver agreement for FVH-T-ASPECTS was $k=0.72$ (95% confidence interval [CI], 0.62–0.81), for FVH-O-ASPECTS was $k=0.71$ (95% CI, 0.61–0.80), and for FVH-I-ASPECTS was $k=0.74$ (95% CI, 0.65–0.83). In our study, subtle FVH-O-ASPECTS were observed in 49 patients (48.5%) and prominent FVH-O-ASPECTS were observed in 52 patients (51.5%). As shown in Table 1, subtle FVH-O-ASPECTS has a lower baseline NIHSS score (14.5, $P=0.016$), lower baseline cholesterol (149.1±38.1 versus 167.0±48.9, $P=0.043$), larger infarct volume (46.5 versus 13.7, $P=0.001$), and more patients with lower ASITN score (73.5% versus 48.1%, $P=0.009$). The number of patients with a favorable clinical outcome was also smaller in subtle FVH-O-ASPECTS group than prominent FVH-O-ASPECTS group (6.1% versus 30.8%, $P=0.002$). As to HT, there was no difference in these 2 groups (38.8% versus 25.0%, $P=0.137$).

As shown in the details of Table 1, 101 patients were graded as subtle FVH-I-ASPECTS group (64/101, 63.4%) and prominent FVH-I-ASPECTS group (37/101, 36.6%). Compared with prominent FVH-I-ASPECTS group, subtle FVH-I-ASPECTS group has a lower baseline NIHSS score (13.5 versus 20.0, $P=0.001$), smaller infarct volume (13.0 versus 65.0, $P<0.001$), and less patients with low ASITN score (51.6% versus 75.7%, $P=0.017$). More patients in subtle FVH-I-ASPECTS group had a good clinical outcome than prominent FVH-I-ASPECTS group (26.6% versus 5.4%, $P=0.009$). Patient in subtle FVH-I-ASPECTS group also had less HT after ET (23.4% versus 45.9%, $P=0.019$).

Clinical and Imaging Outcomes
Variables associated with a favorable clinical outcome are shown in Table 2. Patients’ age ($P=0.013$), history of diabetes mellitus ($P=0.078$), baseline NIHSS score ($P<0.001$), FVH-O-ASPECTS ($P<0.001$), FVH-I-ASPECTS ($P=0.009$), and ASPECTS indicates Alberta Stroke Program Early CT Score; CI, confidence interval; FVH, fluid-attenuated inversion recovery vascular hyperintensity; FVH-I-ASPECTS, FVH-ASPECTS inside DWI-positive area; FVH-O-ASPECTS, FVH-ASPECTS outside DWI-positive area; FVH-T-ASPECTS, Total FVH-ASPECTS; HT, hemorrhagic transformation; mRS, modified Rankin Scale; and OR, odds ratio.

### Table 2. Logistic Regression Analysis of Factors Associated With Clinical and Radiological Outcome

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>mRS≤2 (n=19)</th>
<th>mRS≥3 (n=82)</th>
<th>$P$ Value</th>
<th>OR (95% CI)</th>
<th>$P$ Value</th>
<th>OR (95% CI)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVH-T-ASPECTS</td>
<td>9.0 (7.0–11.0)</td>
<td>8.0 (4.0–10.0)</td>
<td>0.187</td>
<td>8.0 (4.0–10.0)</td>
<td>0.450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVH-O-ASPECTS</td>
<td>8.0 (6.0–10.0)</td>
<td>4.0 (2.0–8.0)</td>
<td>&lt;0.001</td>
<td>1.335 (1.063–1.677)</td>
<td>0.013</td>
<td>5.0 (2.0–8.0)</td>
<td>0.293</td>
</tr>
<tr>
<td>FVH-I-ASPECTS</td>
<td>0.0 (0–2.0)</td>
<td>2 (0–4.25)</td>
<td>0.009</td>
<td>0.925 (0.561–1.524)</td>
<td>0.759</td>
<td>1.0 (0–3.5)</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Figure 2. Location and frequencies of fluid-attenuated inversion recovery vascular hyperintensity (FVH) according to the surface of distal Alberta Stroke Program Early CT (ASPECT) territories. A, Number of patients with FVHs in different ASPECT area. B, Number of patients according to different FVH distribution. MCA indicates middle cerebral artery.
infarct volume ($P=0.006$), original thrombolysis in cerebral infarction (oTICI) score ($P=0.015$), and HT ($P=0.006$) were included in our analysis. After adjusting for representative variables, higher FVH-O-ASPECTS (odds ratio, 1.3; 95% CI, 1.06–1.68; $P=0.013$) appeared as independent predictors of favorable outcome (Figure 3).

As shown in Table 2 and Figure 4, 32 patients (32/101, 31.7%) had HT after ET. Although higher baseline NIHSS score ($P=0.012$), higher blood glucose ($P=0.016$), history of anticoagulation therapy ($P=0.066$), higher FVH-I-ASPECTS ($P=0.016$), infarct volume ($P=0.010$), and lower ASITN score ($P=0.041$) were related to HT in univariate...
analysis, in the multivariate analysis, only history of anticoagulation therapy (odds ratio, 4.7; 95% CI, 1.26–17.12; \( P=0.021 \)) and higher FVH-I-ASPECTS (odds ratio, 1.3; 95% CI, 1.04–1.51; \( P=0.019 \)) emerged as independent predictors of HT.

Discussion

Our novel results demonstrate that the number of distal FVH-ASPECTS has no prognostic value in acute MCA occlusion patients undergoing ET, yet FVH topography is key. Distal FVH-ASPECTS measured outside the DWI lesion is associated with good clinical outcomes. In addition, distal FVH-ASPECTS measured inside the DWI lesion is predictive of hemorrhage transformation. FVH topography and juxtaposition to DWI lesions, not number, can serve as an imaging selection marker for ET in acute MCA occlusion.

FVH is related with a higher grade of collateral circulation distal to large-vessel stenosis or occlusion,\(^6\) and the presence of FVH ranges from 45% to 100% in stroke patients with intracranial arterial occlusion.\(^7,8\) In this study, we included patients with proximal MCA occlusion and all of them were imaged within a short time, which can explain the high prevalence of FVH (97%). In addition to the high prevalence of FVHs, the distribution of the FVHs in our study is also similar to the previous study.\(^13\) As we know, the underlying mechanism involved in the FVH presence is a slow blood flow through the leptomeningeal collaterals.\(^3,15,16\) After proximal MCA occlusion, leptomeningeal collaterals from anterior carotid artery or posterior carotid artery open and the blood pressure falls when moving from borderzone areas (M1, M6) to more proximal areas (M2, M5). Then, it may be the reason why more FVHs were observed in M2 area than M1 area in our study, which is also proved by the previous studies.\(^13,17\)

The prognostic value of FVHs has been widely investigated by previous studies,\(^7,8,13\) and discrepancies have been attributed to differences among populations, imaging time, and FVH classifications. Similar to the previous study,\(^10\) our study got the result that total FVHs within MCA territory had no prognostic value. However, we found that FVHs outside DWI lesion had a good prognostic value in patients with acute proximal MCA occlusion. Extent of FVHs was associated with the presence of a PWI–DWI mismatch,\(^19,20\) and FVHs beyond the DWI lesion mean larger amounts of tissue at risk of infarct expansion. Then, after acute MCA occlusion, patients with more FVHs outside DWI lesion may benefit better clinical recovery because recanalization of occlusion artery can save at-risk tissue.

HT, the major complication of ET, is associated with increased stroke morbidity and mortality.\(^21\) Several brain imaging approaches, including MRI enhancement patterns, T2*-permeability MRI,\(^22\) apparent diffusion coefficient,\(^23\) and very low cerebral blood volume,\(^24\) have been evaluated to predict HT after stroke. Furthermore, collateral circulation has also been associated with HT in patients where recanalization occurs.\(^25\) In this study, we found that FVHs inside DWI lesion was associated with HT in acute MCA occlusion. As we know, reactive oxygen species and blood-derived factors MMP-9 (matrix metalloproteinase-9) have emerged as important mediators in early HT.\(^21\) Within 30 minutes of focal cerebral ischemia, ischemic stroke elicits a robust activation of the immune system, and circulating leukocytes adhere to vascular endothelial cells.\(^26\) More FVHs inside DWI lesion represent the ischemic penumbra. Then, more FVHs distributing outside the DWI lesion means that more tissue at risk can be saved by ET.

Conclusions

Acute MCA occlusion patients with more FVHs (FVH-ASPECTs ≤4) outside DWI lesion and less FVHs (FVH-ASPECTs ≥2) inside DWI lesion have better outcome after ET. Then, FVHs pattern can provide as a novel imaging criteria for patient selection of ET.

Sources of Funding

This study was supported by grants from NIH-NINDS (Liebeskind—K24NS072272), American Heart Association (AHA; Scalzo—16BGI27760152), National Natural Science Foundation of China (grant no. 81220108008 and 81000501), Jinling Hospital Medical Scientific Research Projects (2012003), and Clinical Medical Center Program of Jiangsu Province (Neurology Center).

Disclosures

None.

References

FVH Topography Serves as Patient Selection Marker

Liu et al. 2017


Fluid-Attenuated Inversion Recovery Vascular Hyperintensity Topography, Novel Imaging Marker for Revascularization in Middle Cerebral Artery Occlusion
Dezhi Liu, Fabien Scalzo, Neal M. Rao, Jason D. Hinman, Doojin Kim, Latisha K. Ali, Jeffrey L. Saver, Wen Sun, Qiliang Dai, Xinfeng Liu and David S. Liebeskind

*Stroke*. 2016;47:2763-2769; originally published online September 22, 2016;
doi: 10.1161/STROKEAHA.116.013953
*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2016 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/47/11/2763

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org/subscriptions/